# Los Alamos National Laboratory
# Spallation Neutron Source

## SNS Wire Scanner System
## Preliminary Design Review

**Response to the Review Committee Report**

Work Package Manager: ____________________
Mike Plum

SNS-2 Group Leader: ____________________
Mike Lynch

SNS-3 Group Leader: ____________________
Kirk Christensen

SNS-4 Group Leader: ____________________
Stan Brown

Physics Review: ____________________
Jim Stovall

Project Office Review: ____________________
Will Fox

Division Director: ____________________
Don Rej

Work Package Manager:
The Work Package Manager is responsible for generating constructive and specific responses to the review committee's recommendations. Responses should be generated in a timely manner. Responses should incorporate the action to be taken, who is responsible for the action, the time frame by which the action will be completed if required before the Final Design Review, and any impact to the project cost, schedule or scope. Work Package Manager signature means that all responses having no significant impact on project cost, schedule, or scope will be incorporated into the design of the system. Responses that involve a significant impact to project cost, schedule, and scope must include a description of the impact and be approved prior to implementation by the Project Office.

SNS-2 Group Leader:
Reviews responses for overall technical merit, cost effectiveness and reasonableness for implementation. Reviews responses relative to interfaces with other accelerator systems and for potential impact to these systems.

SNS-3 Group Leader:
Reviews responses for overall technical merit, cost effectiveness and reasonableness for implementation. Reviews responses relative to interfaces with other accelerator systems and for potential impact to these systems.

Physics Review:
Reviews responses for impact to physics design.

Project Office Review:
Review responses for impact to project cost, schedule and scope. Approves or disapproves responses which impact project cost, schedule or scope prior to their implementation.

Division Director:
Provide final review and approval of responses prior to distribution.

Responses to the Design Review will be distributed to:

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The SNS Wire Scanner System Preliminary Design Review was held at LANL on July 17, 2001. We received the review committee's report on August 13, 2001. We thank the review committee for their insightful observations and suggestions, and their timely response. In this document we shall address each observation and suggestion. Each item that requires action on our part will be tracked and the progress will be reported at the final design review.

## Observations and Suggestions

**Committee Observation** – Important questions remain unanswered concerning the advisability of and conditions for installation and use of **wire scanners near superconducting RF cavities**. Concerns center on the formation or release of particulate matter that may contaminate superconducting surfaces (from actuator mechanisms, hot wires, breaking wires, etc.) A secondary concern is the heat load on the cryogenic system due to energy deposited by beam loss caused by the wires. It is not likely that conclusive data will be available to address all concerns before implementation decisions must be made.

**Recommendation** – LANL, JLAB, and ORNL collaborators should determine **whether or not any useful tests could be defined** and carried out at the JLAB vertical test facility.

*Response – It would indeed be illuminating to make some tests at the JLab facility. However, JLab has no plans to do so. The JLab stance is "any wire material making its way into the cavity will destroy the cavity performance and must be avoided."*

**Committee Observation** – LANL has completed a good candidate mechanical design for the **superconducting linac wire scanner actuator**. Work remains on wire material selection and mounting design.

**Recommendation** – LANL, JLAB, and ORNL collaborators should very soon begin detailed **specification of the processing, cleaning, and assembly steps** for wire scanners that will need to be performed probably in a JLAB clean room. It is important to identify if and how these procedures may drive design parameters.

*Response – We agree. We have received drafts of the cleaning process, and we are working with JLab to determine its impact on the wire scanners.*

**Committee Observation** – The **laser wire** is appealing as a cool and clean solution to the beam profile measurement problem in the superconducting linac and everyone would like the idea to work. The efforts at BNL are to be commended. However, the committee has several **questions and concerns**:

1) Can comparison of before and after neutralization signals from beam current monitors provide the required profile resolution? Over what range of beam currents? Over what range of beam energies? (Neutralization cross sections are significantly smaller at 1GeV than at the energy of the BNL demonstration.) Are there alternate signal detection methods? If direct measurement of the neutral atoms is necessary to provide sufficient signal-to-noise for the required profile measurements, this is probably a showstopper.

   *Response – Calculations indicate that S/N ratios from the Laser Wire are approximately equal to the Carbon Wire at 1 GeV. The energy dependence of the laser cross section and beam heating in the carbon both favor the Laser Wire as one moves to lower energies. We have completed a proof-of-principle experiment at 750 keV and are in the midst of one at 200 MeV to confirm the calculations. We agree that direct measurement of either neutrals or electrons significantly reduces the appeal of the Laser Wire, as either approach adds significant cost and complexity and requires one to introduce additional hardware in the vacuum.*

2) Is the bandwidth of the proposed SNS beam current monitor system adequate? (Presumably the duration of the laser pulse and the resulting neutralized slice of beam will be only nanoseconds.) Is the installed system noise adequately understood and controlled for detection of small differences between two current measurements? Are the laser timing control and the beam current signal digitization rate sufficiently accurate and compatible for reliable capture of the required signal? What will be the impact of normal beam current variations during the beam pulse and pulse to pulse?

   *Response – Bandwidth of the pickup is 1 GHz, not including the low beta (Bessel factor) pickup response. Our baseline digitizer for BCM is 65 MS/sec, but the most recent release of this chip is now 100 MS/sec. If one performs optimal filtering of the 10 ns pulse to maximize S/N, the bandwidth is just right. In principle the differential current measurement approach should satisfactorily address the current variation and background noise concerns. In practice we seek to verify this in the 200 MeV POP experiment. Timing concerns will be addressed at the same time.*

3) Are commercially available lasers compatible with the radiation environment near the beam line or is remote location required?

*We have installed a 50 mJ/pulse laser (Big Sky Ultra Compact) in a high-radiation environment at the AGS. The laser will fire continuously and we will monitor the pulse with a photodiode detector and a pyro-electric joule-meter and the radiation environment with a integrating dosimeter. Based on the result of this measurement the decision will be made about mounting the laser head away from the beam line in a shielded housing. Beam divergence limits the distance from the laser to the beam line to a few meters without transport optics.*

4) Are the procurement, installation, operational, and maintenance costs of the laser wire system adequately understood and acceptable? Might it be more cost and maintenance effective to use a small number of lasers and switch or split the light beam to multiple profile measurement stations?

   *It is possible to use a single laser for several measurement stations however no designs have been made. Any such scheme will involve transporting the laser beam over path lengths of many meters making alignment more critical and probably requiring transport optics. Using a separate laser head for each station is mechanically much simpler. The cost of a single station has been presented in the review. If this cost is too high we will investigate using fewer lasers than measurement stations, cooling the laser heads from house water, and powering several laser heads from a single power supply.*

**Recommendation** – **Continue laser wire R&D**; transforming that idea into a useful instrument would be a valuable contribution to beam instrumentation. Until satisfactory answers can be provided to the above questions it would be **risky for SNS to rely on the laser wire as a baseline beam profile monitor**.

*Response – Noted. A laser wire R&D program has been initiated. The laser and physical wire methods will be developed in parallel for as long as possible. A downselect decision is expected in Spring 2002.*

**Committee Observation** – **Halo measurement** remains a lively topic though requirements have not been quantified or specified. Ultimate SNS performance may be limited by halo development and the resulting beam loss.

**Recommendation** – SNS management is encouraged, for the sake of efficiency, to explicitly state the extent to which direct halo measurement capability is or is not to be included in the baseline instrumentation. Halo measurement is not likely necessary to meet initial project milestones. Nevertheless, the committee believes it will **ultimately** be **important** for SNS to not simply observe beam loss due to halo, but **to actually measure and diagnose halo** properties to control losses.

*Response – After many discussions with Linac and Ring physicists, we came to the conclusion that halo measurements are not necessary for the CD4 and the initial phase of intensity ramp up. The MPS people are also in favor of excluding the halo measurement from the present wire scanner system. If we need to measure the halo due to unforeseen physics at startup, then we require a separate system, which could have a substantially different interface to the MPS.*

**Committee Observation** – The question was asked by an audience member whether the **quantity and location of Linac wire scanners** had been agreed upon. Mike Plum answered in the affirmative and cited quantities of 5 in the DTL, 8 in the CCL, and 32 (minus empty cryomodule locations) in the SCL. Quantitative beam physics justifications were not offered in support of the quantity and location requirements.

*Response – It is true we do not have a complete set of beam physics justifications. We are working to remedy that. For example, a recent beam physics study recommended adding more wire scanners to the CCL to check the DTL to CCL match (D. Jeon et al.,"Transverse matching of CCL to DTL using the rms beam size from wire scanners.") The same study also found that the 10% accuracy requirement on the width measurement is sufficient to determine if the DTL is correctly matched to the CCL.*

**Committee Observation** – Selection of **wire material** for scanners was identified as an unresolved design issue.

**Recommendation** – Take advantage of the LEDA setup to **study wire material and heating issues** under real beam conditions.

*Response – We are in regular contact with LEDA beam diagnostics personnel, and we continue to discuss what they have learned about wire scanners. We plan to take full advantage of the LEDA results.*

**Committee Observation** – Quantitative specifications for **lifetime radiation dose** do not seem to exist for wire scanner actuators and other beam line instrumentation devices.

**Recommendation** – **Radiation dose tolerance requirements should be specified**. SNS Oak Ridge should provide best estimates of the radiation environment as a function of position within the tunnel. These estimates should include the short-term loss conditions experienced during tune up, the steady state losses expected during beam delivery and an overall dose estimate per year of operation.

*Response – The ORNL target group has made calculations based on controlled beam losses ( losses due to magnetic and gas stripping subject to the designed vacuum pressure). There will be a report on these studies. To summarize, the maximum radiation dose equivalent to the silicon quality factor at the surface of beam pipe is listed here:*

1) *DTL = 3 rads/hr*
2) *CCL= 14 rads/hr*
3) *SCL medium beta = 2.5 rads/hr*
4) *SCL high beta = 8 rads/hr*
5) *SCL spare module section = 30 rads/hr.*

*For a 30 year facility lifetime, 10 months operation per year, the maximum dose from normal operations is 30 x (10/12) x 365 x 24 x (30 rads/hr) = 7 Mrads. Since the tune up and off-normal loss rates occur for such a short time compared to the normal loss rates, the overall radiation exposure will be only slightly more than that for normal losses. All beam diagnostics components located by the beam line should therefore ideally be rated for 10 Mrads.*

**Committee Observation** – The plan presented for detecting signals from Linac wire scans is to use **secondary emission signals** AC coupled from the wires. This is compatible with the **three-wire mounting geometry** that presents multiple wires simultaneously to the beam. This geometry precludes using loss monitor or photomultiplier signals to obtain unambiguous profile information with the wires and may be a limiting factor in using the wire scanners to measure beam halo where secondary emission signals will be very small. The geometry was chosen to reduce the required actuator stroke; a stroke that must be quite large in the Ring and some transport locations, but not so much in the Linac.

*Response – Noted.*

**Committee Observation** – Fly mode and step mode operation of the wire actuators were identified and scan times for individual profiles were presented. It was not apparent if these individual **scan times** are consistent with making enough measurements in a timely manner to represent a useful set of beam data. How many wires can scan at once? … from the beam physics perspective? … from the allowable beam loss perspective?

*Response – A maximum of about 0.5% of the beam hits the wire and gets converted to protons. This is a negligible effect on the downstream wire scanners, especially considering that the protons are mismatched to the lattice and are quickly lost. For crossed wires on the same fork, the displaced x and y wires will minimize the effect of the upstream wire on the downstream wire*

*The allowable beam loss is about 1 Watt/m during full-current operation (1.4 mA average current). 1 watt/m corresponds to about 100 nA, 10 nA, and 1 nA per meter at 10, 100, and 1000 MeV respectively. The wire scanners will be run at reduced duty factor (50 to 100 ms, 1 to several Hz) to avoid damaging the signal wires. For 10 Hz, 100 ms duty factor, the average beam current is 1.4 mA. About 0.5% of the beam, equivalent to about 7 nA, is converted to protons lost over several FODO periods. This is less than 1 nA per meter, and should not exceed the loss limit.*

*Therefore the number of wires that can be run at a time is not limited by beam physics, but rather by beam loss, and the limit depends on the beam energy and the beam duty factor. For example, at the worst case of 1000 MeV, 5 wires could be run with a 2 Hz beam.*

**Committee Observation** – Tom Shea stated his **requirement for remote calibration/health monitors** on all beam instrumentation systems, but detailed functionalities appear to be left up to designers, not supplied to them based on operational requirements. News of the calibration/health monitoring requirement apparently had not reached at least one of the presenters.

**Recommendation** – Timely **communication** between “customer” and “supplier” should be strengthened in this area.

*Response – We have formed a jointly agreeable strategy to test from prototype to the final hand off product. Both supplier and consumers are working hand in hand to make sure all requirements are understood by all of us. For the first iteration, please refer to the hand-off criteria documents.*

**Committee Observation** – **Ring beam profile measurement specifications** are in a very preliminary stage with incomplete and unresolved requirements.

**Recommendation** – Effort needs to be put into **understanding and documenting what beam physics information** is expected, required, and obtainable from beam profile measurements in the Ring. This will lead to quantifiable instrument specifications.

*Response – The intent of Diagnostics is to provide turn by turn profiles with both IPMs and carbon wires through the acceleration cycle. How this information is utilized by AP will evolve over the course of many years.*

**Committee Observation** – Secondary emission from the wire was proposed as the preferred **Ring wire scanner signal**, although it was mentioned that the situation was different one week prior to the review. The committee noted two potential signal contamination sources with this approach: 1) electromagnetic pick-up on the wire of the strong 1Mhz beam signal frequency component due to the gap in the circulating beam, and 2) interactions between the wire and background electrons in the Ring.

**Recommendation** – **See recommendation above**. When requirements and specifications are clear, then consider whether using some type of beam loss monitor might not provide a cleaner, more unambiguous signal.

*Response – The intent is to use BLMs for the carbon wire scanner in the Ring.*

**Committee Observation** – The committee was left with an uncomfortable feeling following Liaw's presentation on **carbon wire heating in the Ring**. Many numbers presented in the talk, e.g. wire temperatures, were different by nearly a factor of three from those contained in the handout. The committee did not understand the reason for the large changes within a day of the review. Also, heating of a conductive wire in the Ring due to electromagnetic coupling to the circulating beam current (up to 50 amperes) was not included in the analysis. This heating has proven to be a problem at CERN causing them to choose ceramic wires.

*Response – Apologies to the committee for the discrepancy between handout and presentation calculations. There was significant confusion about the effect of injection painting on wire heating. The problem only became clear during a dry run for the review, and was then immediately corrected. Heating due to electromagnetic coupling to the beam current was a concern for the ultra-short bunches in LEP. We examined this in detail several years ago, and while the effect is much more significant in the Linac than the Ring (where the bunches are comparatively long), it is not a concern anywhere in SNS.*

**Recommendation** – Take advantage of the LEDA setup to **study wire material and heating issues** under real beam conditions.

*Response – We are in regular contact with LEDA beam diagnostics personnel, and we continue to discuss what they have learned about wire scanners. We plan to take full advantage of the LEDA results.*

**Committee Observation** –Integration of the **wire scanners with the Machine Protection System** (MPS) is an important issue to protect from burning out wires and/or causing excessive beam loss. It is likely that this integration for normal operational modes is well in hand, but of more concern is how "off-normal" modes, like putting wires near the edge of high power beam to measure halos, will be handled with the MPS. Of course, "false trips" must be minimized also.

**Recommendation** – Attempt to **identify** as many **“off-normal” modes** as possible early on, perform some risk analysis, and define how these modes will be handled with the MPS. Determine acceptable margins of safety and recognize residual risk. Is it necessary or even feasible to develop and incorporate wire temperature monitors into the MPS in a useful manner?

*Response – As of now, the limit switches will reduce the pulse length to the predefined 50 microseconds and they cannot be bypassed by a physicist or an operator. An MPS expert is required to install a bypass. The risk of damaging the wires is well known and the decision to increase the pulse length will not be casually treated.*

**Committee Observation** – **Uniformity of electronics** systems remains a goal that should be pursued. The committee observed instances where this goal is being compromised.

*Response – Noted – see below.*

**Committee Observation** – **Stepper motor drive electronics** – The super conducting cavity tuners use approximately 100 stepper motor drive “bricks”. They are probably different than the one chosen for the beam diagnostics actuators. Additionally, they are designing a “snubber” module which is provides signal conditioning between the motor and the drive “brick”.

**Recommendation** – The beam diagnostics team and SRF electronics team at LANL should consider standardizing on a single set of drive electronics. The need for the snubber electronics should be understood, as a similar circuit may be required in the linac portion of the machine.

*Response – Good idea. We have contacted JLab to learn about their stepper motors and any requirements they may have on stepper motors near the SNS cavities.*

**Committee Observation** – Consider using the standard BPM/BCM data acquisition systems. One should be able to reduce the clock rates and improve the effective bit counts to 14 bits. There probably isn’t a strict requirement for synchronizing of data acquisition and motor drive electronics. With a one-minute scan time, software synchronization should be sufficient. Consider ways to combine multiple channels into one computer chassis. Evaluate the option of using higher density data acquisition modules. The main concern with using higher density National Instrument modules may be sampling the data synchronously, as is done on the NI-6110. What is the impact on the measurement? Additionally, consider using a NI SC2040 sample and hold module as a combination signal conditioning and terminal block for increasing the density of signals within a single computer chassis. For instance, a pair of SC2040 modules, a pair of 8-differential channel NI-6052 DAQ modules and a quad stepper motor driver module would allow four wire scanners to be controlled by one computer chassis. Of course cable run lengths, computing speeds, and many other factors may make such a change impractical.

*Response – We have considered using the BPM PCI motherboard solution, and have discarded it. We believe it is more cost effective and a more integrated solution to use off-the-shelf motion control and data acquisition components from National Instruments. We have considered having multiple channels in one computer chassis, and it is in fact part of our baseline plan to have two channels per computer chassis.*

**Committee Observation** – The planned **presentation** on HEBT, Ring, and RTBT wire scanner actuators was **omitted** due to lack of time.

**Committee Observation** – In the big picture, it is clear that **management of the beam instrumentation effort** is still in flux. This is not necessarily a surprise or a problem in an enterprise at this stage. We observe shuffling of responsibilities between BNL and LANL, new assignments for software integration responsibility, remaining confusion about requirement/specs e.g. for on-line/remote calibration/health monitor for instruments, etc. The committee commends the staff for recognizing the need to adapt and to formally address changing needs as the project develops. The review acknowledged the necessity to address systems issues such as:

1) Handoff strategy for task responsibilities and for pieces of hardware – It is important that each collaborator knows the scope of his responsibility and when each piece of the job is complete. This is an important cost issue; if handoff is not defined, everyone will continue to hang around at the expense of the project until the machine is running.

2) Systems integration – This is SNS Oak Ridge responsibility and represents a cost and schedule issue. Are there reviews of systems issues? There would be a much better framework within which to review detailed designs if the integrated plan was clearly understood.

   *Response – We have started with the Acceptance Strategy documents. These documents have been revised by the partner labs and agreed upon by the ORNL-SNS. The steps listed include testing the prototype, first article and production systems. Documentation and integration have also been agreed upon by ORNL-SNS and the partner labs.*

**Committee Observation** – Biggest performance and cost **risks** are in the areas of incomplete and/or misunderstood requirements and specifications, hand-off considerations between collaborators and SNS Oak Ridge, and systems integration issues.

*Response – We agree. We have written formal Acceptance Strategy documents to reduce this risk. The documents define the roles and responsibilities. The requirements and specifications are clearly defined in the Design Criteria Documents.*

**Committee Observation** – Within the framework of the presently understood requirements, the design of the **Linac wire scanners**, especially the mechanical actuators, **appears to be well in hand for the PDR stage**. Selections of wire material and wire attachment are outstanding issues, as is the definition of processing requirements for scanners destined for the SCL. **Ring wire scanners**, requirement definitions and designs, are at a considerably more **premature stage**. We see good progress and no obvious showstoppers, but there is much work to be done.

*Response – Observation noted.*